Opportunities for Low Temperature Research aboard the Space Station

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A cryogenic Space Station facility is being developed by the Jet Propulsion Laboratory and industrial partners to support the microgravity needs of the international scientific community. The facility will be attached to the Japanese Experiments Module's Exposed Facility and will operate with a 6 month helium cryogen lifetime. Flights of the facility are planned at 2 year intervals starting in 2003 with each flight accommodating multiple scientific experiments. Capabilities, conceptual designs and development plans for the facility will be discussed along with a summary of potential near term flight candidate experiments.

1. BACKGROUND

In 1985 the Superfluid Helium Experiment, developed by the Jet Propulsion Laboratory, demonstrated the containment and control of liquid helium in space and the feasibility of supporting a science instrument insert within a liquid helium dewar [1]. In 1992 the Lambda-Point Experiment, developed by Stanford University, JPL and Ball Aerospace, added a nanokelvin high resolution thermometry to this capability which allowed a precise test to be performed of the Nobel Prize winning Renormalization Group Theory (RGT) of critical phenomena [2]. In 1997, the Confined Helium Experiment (CHeX) will use the unique properties of liquid helium to perform a high resolution test of the theory of finite size effects [3]. The last of the Shuttle based experiments in 2000, Critical Dynamics in Microgravity (DYNAMX) will study dynamic critical-point phenomena driven far away from equilibrium by introduction of a heat current [4]. While necessary and productive these Space Transportation System (STS) based experiments are short term, lasting no longer than ten days; expensive, and requires up to 7 years for development. In the early eighties this program was supported by a small community of investigators supported by NASA's Physics And Chemistry Experiments Program (PACE). This community expanded in the late eighties and early nineties to involve many major Universities across the United States. Today, numerous National and International Investigators (U. S., Japan, Russia, Germany, the U.K. and Canada) have defined microgravity physics science objectives in critical phenomena, relativity, low temperature physics and laser cooling of atoms. These objectives are in the process of being combined into long range goals for testing fundamental principles of physics, exploring the range of validity of universality principles, and determining scaling laws only possible in the microgravity of space. Future experiments require longer duration experiment times than possible on the STS. The National Research Council's Space Studies Board (SSB) and other advisory groups have recommended that NASA develops a cryogenic capability On the Space Station so that these experiments can be conducted there.

2. FACILITY REQUIREMENTS

In determining the requirements for a space station facility the community and NASA evaluated the strengths and weaknesses of the STS program. Strengths included reuse of major hardware and software components by an experienced infrastructure of people and facilities. Weaknesses were few flight opportunities with long development times complicated by the involvement of too many NASA Centers resulting in redundancy and cost growth; complex interfaces between investigators, industry, and NASA which resulted in a deterrent to potential investigators willingness to undertake the responsibility for a flight experiment and the high cost per experiment. The Low Temperature Microgravity Physics Facility (LTMPF) will be designed to meet the following high level requirements: Support a broad range of fundamental physics and applied science experiments; support multiple experiments/instruments per flight; provide up to 6 months of experiment duration; simplify the mechanisms for investigator involvement; provide for remote operation at PI facilities; provide passive vibration isolation; monitor acceleration and radiation environments; reduce development time to 3 years; significantly reduce the cost per experiment; simplify reflight and provide more frequent access to space; and archive data to provide access to a wider research community.

3. FACILITY DESCRIPTION

The LTMPF is a reusable self-contained cryogenic facility designed for 6 months of cryogenic lifetime operating as an attached payload to the Japanese Experiment Module's Exposed Facility. The facility carries about two hundred sixty-seven liters of helium and accommodates two instrument inserts, one from either end of the cylindrical facility. In the current design, each instrument must have a diameter of less than 20 cm and not be longer than 50 cm. Each instrument mass is limited to 50 kg. The facility provides vibration isolation, instrument control, data collection, acceleration and radiation environment monitor and all interfaces with the JEMEF.

Transport is effected through use of the Shuttle Orbiter from the Kennedy Space Center. The dewar is last serviced on the Pad prior to payload bay door closure and flies passively attached to the Japanese Experiment Logistics Module.

Transfer from the Orbiter to the JEMEF is accomplished by crew Internal Vehicle Activity using Orbiter and Space Station Remote Manipulator Systems.

Turn-on and check-out will be performed at the ISS Payload Operations Central Center (POCC) and routine operations will be conducted from individual remote POCCs located at investigator facilities using "Bent Pipe" Telemetry and Command services from the ISS POCC. The ISS/JEMEF services are limited to minimal telemetry (24 Kbps) and command (600 commands/day) processing and downlink, power (500 Watts), and attach/detach crew operations. The facility will operate continuously for 6 months or until the cryogen is expended and then wait passively for the next opportunity to transport back to Earth.

During the 6 months operation of one flight, a second pair of instruments would have been developed, integrated and tested with another flight dewar in preparation for the next flight. Upon return to Earth the facility will proceed through a brief checkout at) the instruments and dewar from the first flight will be removed and replaced with the flight ready instruments and dewar for the next flight. This exchange of instruments and dewars will allow reflight as often as every 20 months.

4. IMPLEMENTATION

LTMPF will be implemented by a science, Industry and JPL partnership where partnership is defined as joint participation through all phases of definition, development and test with contractual responsibilities which share the risks and the rewards. Science participants will be determined through the NASA Research Announcement (NRA) peer review process. Two potential flight experiments have recently been selected [5]. Two additional flight definition investigations are targeted to be selected from a NRA solicitation to be released in November, 1996. Subsequent NRAs will be issued at two year intervals for future experiment selections. The Industry partner, Ball Aerospace and Technology Corporation (BATC), responsible for development of the facility, was selected through a competitive technical selection process developed by JPL for this program. JPL is the NASA Center of Excellence for Microgravity Physics and is responsible for development of the instruments and management of the overall activity.

Ball and JPL will be involved early in the process when the science and the Space Station interfaces are under definition. This will allow science, Ball and JPL to co-engineer the instruments and the facility consistent with a good understanding of science requirements prior to hardware development planned to begin in 1999.

This work was carried out by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA.

REFERENCES

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[5] A ^{3}He critical point experiment with Marty Barmatz as principal investigator, and a universality test along the helium lambda-line with 101101 Lipa as principal investigator.